

Tier 3 Thermostat Calibration Study

Presentation to the EWR Collaborative

April 18, 2023





Agenda

01 Background

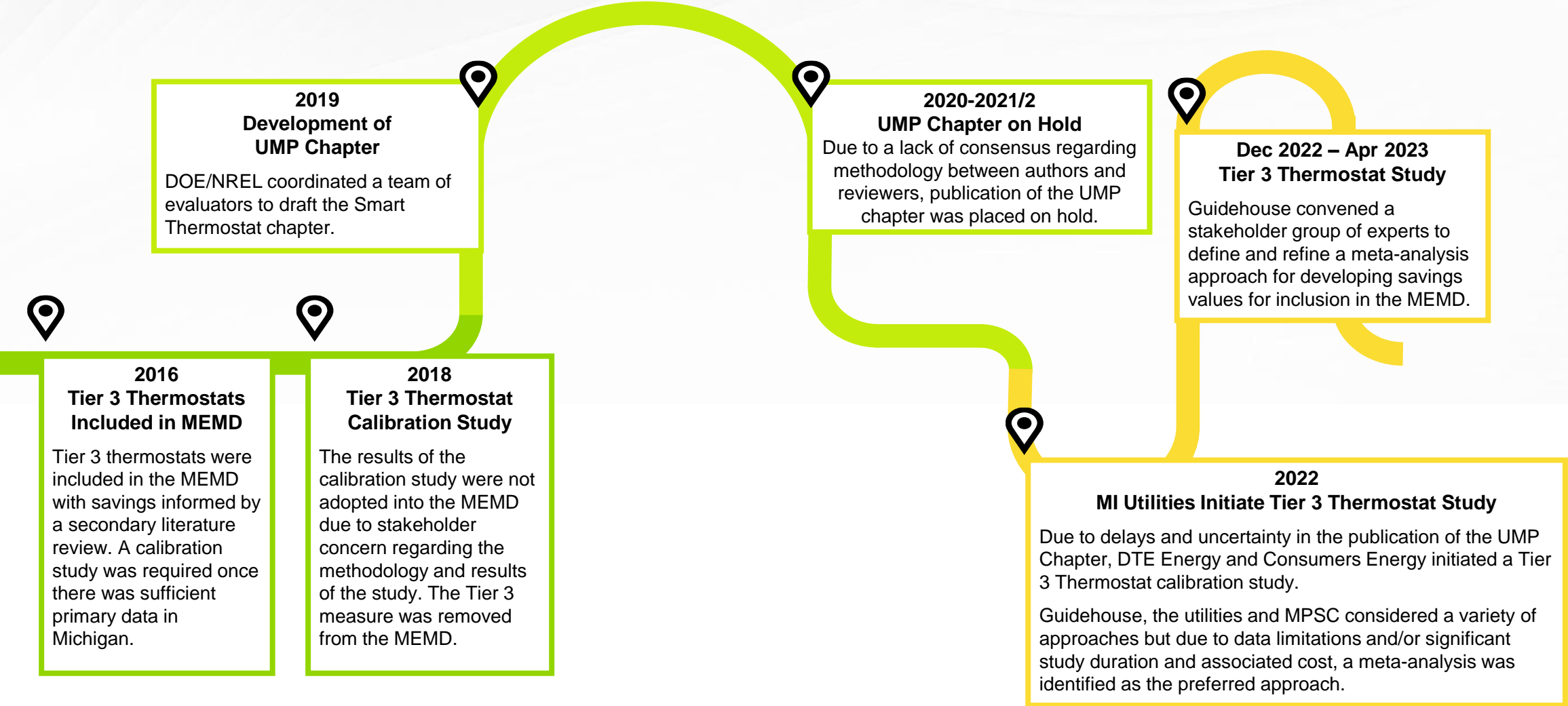
02 Stakeholder Engagement Process

03 Analysis Approach

04 Results

Background

Background



Stakeholder Engagement Process

Stakeholder Engagement Process

Initial Stakeholder Meeting (Jan 11)

- Provided details on overall approach and proposed study inclusion criteria.
- Provided additional details associated with the analysis methodology including proposed approach to align, adjust and aggregate savings results across various selected studies.
- Requested stakeholder input on study inclusion criteria, analysis approach and studies that Guidehouse should consider.

Second Stakeholder Meeting (Feb 27)

- Presented list of studies included in the literature review.
- Presented adjustments and weights to derive savings values.
- Provided proposed savings values and information associated with energy modeling to produce MI-specific savings estimates.
- Requested final stakeholder input and feedback on proposed weights and adjustments
- Provided stakeholders with spreadsheet of the aggregated savings calculations

Stakeholder Communication (Apr 06)

- Provided summary of changes incorporated based on stakeholder feedback.
- Provided final savings values to be considered for inclusion in the MEMD.

Stakeholder Roster

Name	Organization
Will Baker	Google Nest
Kevin Bilyeu	DTE Energy
Michael Blasnik	Google Nest
Steve Cofer	The Cadmus Group
Tamara Dzubay	Ecobee
Amy Ellsworth	The Cadmus Group
Joe Forcillo	Consumers Energy
Karen Gould	Michigan Public Service Commission (MPSC)
Pete Jacobs	BuildingMetrics Inc.
Josh Martens	DTE Energy
Lynne McCollum	Consumers Energy
Kahryn Riley	Ecobee
Jim Stewart	The Cadmus Group
Annika Todd	Lawrence Berkeley National Laboratory
Dave Walker	Michigan Public Service Commission (MPSC)

Analysis Approach

Analysis Approach

Summary

- 1 Specified ***inclusion criteria***, down selecting the number of studies included in the analysis
- 2 Developed an ***aggregation approach***, identifying relevant criteria and developing a weighting schema
- 3 Performed an ***analysis of savings*** values, including unit conversion, applying composite weights, and accounting for thermostat optimization

Inclusion Criteria

Thermostat Technology	Heating System Type	Housing Type	Study Source
<p>Include Relevant Smart Thermostat Technology</p> <p>To ensure relevance of measure savings, Guidehouse only includes study results for smart thermostat technologies currently available in the market*</p>	<p>Exclude Electric Heating Results for Heat Pumps</p> <p>Due to the low penetration of heat pumps in Michigan, studies reporting electric heating savings for heat pumps are excluded.</p> <p>Guidehouse does include electric cooling savings for studies where ducted heat pumps are included as a cooling system type as there should not be any significant performance differences in AC and heat pump systems.</p>	<p>Include Single-Family Only</p> <p>Due to the limited number of studies which aim to measure savings for Multi-Family, Guidehouse has limited the analysis to Single-Family**</p>	<p>Include Studies Using Primary Data & Conducted by an Independent Third-Party</p> <p>To provide the most confidence in the set of selected studies, Guidehouse only included studies relying on primary data and that were conducted by an independent third-party.</p>

* Guidehouse defines smart thermostats as thermostats that “can automatically adjust temperature setpoints to optimize performance and achieve energy savings. Common smart thermostat features include two-way communication, occupancy detection (e.g., geofencing, occupancy sensors), schedule learning, and weather-enabled optimization.” *Forthcoming chapter of the UMP*. This exclusion criteria removed studies/savings for programmable and Wi-Fi only thermostats, smart thermostat models that have been discontinued, and studies where the savings result represented multiple measures.

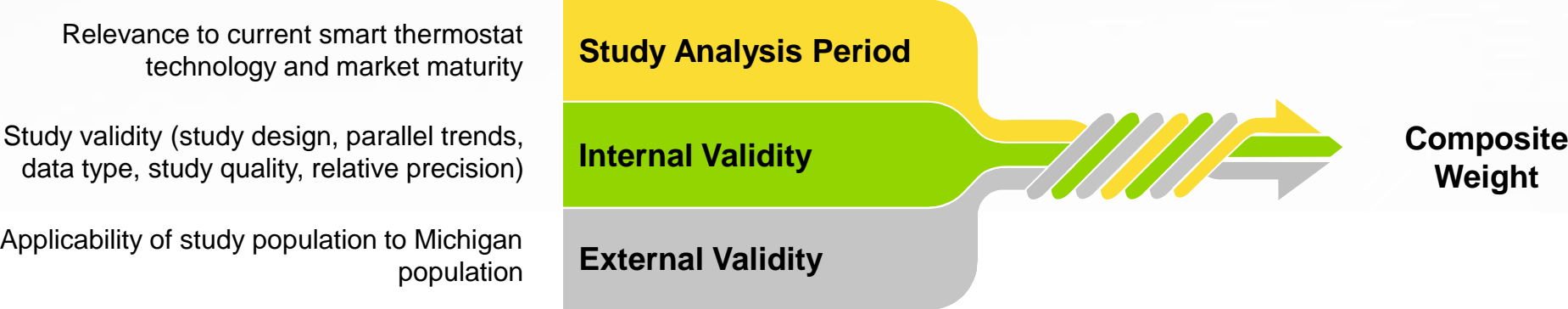
**Two studies reported savings for SF and MF in the aggregate – in both cases MF represented a relatively small portion of the study population (10% or less). Guidehouse opted to include these studies to build a preponderance of evidence to inform the savings value.

List of Selected Studies

Study Title (Source Hyperlinked)	Author	State	Study Year
Northwest Smart Thermostat Research Pilot	Apex Analytics	Washington/Oregon/Idaho	2020
Impact Evaluation of Smart Thermostats-PY2018	DNV-GL	California	2018
Residential Thermostat EE Program Evaluation*	Guidehouse	Confidential	2020
ComEd Advanced Thermostat Evaluation: Final Research Report	Guidehouse	Illinois	2018
Recurve Smart Thermostat Impact Analysis Reports 2015-2017	Recurve	Oregon	2017
When are Smart Thermostats a Smart Investment?	Evergreen Economics/Southern California Edison	California	2018
Michigan Tier 3 Thermostat Calibration Study	Guidehouse	Michigan	2017
PG&E Smart Thermostat Study: First Year Findings (Thermostat 1)	Applied Energy Group	California	2016
Xcel Energy Colorado Smart Thermostat Pilot – Evaluation Report	Nexant	Colorado	2016
ACEEE Evaluation of the Space Heating and Cooling Energy Savings of Smart Thermostats in a Hot-Humid Climate Using Long-Term Data	Florida Solar Energy Center	Florida	2015
Energy Trust of Oregon Smart Thermostat Pilot Evaluation	Apex Analytics	Oregon	2015
Evaluation of the 2013-2014 Programmable and Smart Thermostat Program, 2015 (Vectren)	Cadmus	Indiana	2014
Analysis of Energy Savings for FPL’s Customer Trials of the “” Learning Tstat	Itron	Florida	2014
Getting Smarter? Evidence of Savings from the Nest Thermostat	Navigant (Guidehouse)	California	2015
Residential Smart Thermostats, Illinois, 2015	Navigant (Guidehouse)	Illinois	2015
Vivint Smart Home™ Energy Savings Study Heating and Cooling Results	Vivint Smart Home	USA	2017
Understanding Energy Efficiency Benefits from Smart Thermostats in Southern California	EnergyHub and Vassar College	California	2013
Evaluation of the 2013-2014 Programmable and Smart Thermostat Program, 2015 (NIPSCO)	Cadmus	Indiana	2014
TRM v4.0 Recommendations for Residential Thermostats and Heating and Cooling Equivalent Full Load Hours	Cadmus	Minnesota	2020

Aggregation Approach

Summary of Approach



Aggregation Approach

Study Analysis Period

- Savings values included in the MEMD should reflect current state
- Key considerations
 - Smart thermostat technology continuously evolves via modifications to algorithms pushed “over-the-air”
 - Early adopters may have usage patterns and/or characteristics affecting savings that may be different from current adopters.
- Guidehouse included all studies with a decreasing weight as the study analysis period goes further back in time
 - This approach ensures a sufficiently large number of studies are used to inform the savings value, while emphasizing results from recent years reflecting current technology and market trends

Study Analysis Period	Weight	Number of Studies
2020*	0.30	3
2019	0.25	0
2018	0.20	3
2017	0.10	3
2016	0.07	2
2015	0.05	4
2014	0.02	3
2013	0.01	1
Total	1.00	19

*Three studies included post-period data in 2020, but the analysis periods were intentionally stopped in February/March 2020 to avoid the effects of COVID-19.

Aggregation Approach

Internal Validity: Study Design

- Studies with the highest study design quality should have the largest influence for savings values in the MEMD
- Key considerations
 - Guidehouse developed a weighting scheme based on the study design, consistent with the UMP and dialogue across numerous forums over the past 5+ years regarding smart thermostats
 - Studies using experimental design were given the highest weight
 - Weights for studies using a matching approach to construct a comparison group varied based on approach and likelihood of mitigating selection bias and ensuring parallel trends in energy consumption over time
 - Studies that do not include a comparison group were given a weight of 0, consistent with the guidance included in the draft chapter of the UMP. This includes studies that rely on a within-subject (or pre/post) comparison of energy consumption data, as well as studies that rely on the ENERGY STAR method.

Study Design	Weight	Number of Studies
RCT or RED	0.400	6
Matching, Future Participants	0.300	3
Pooled, Future Participants	0.150	3
Matching, Energy + Demographics	0.100	1
Matching, Energy	0.050	3
No Comparison Group*	0.000	3
Total	1.000	19

*The 3 studies with a study design weight of 0 were effectively dropped from the analysis at this stage.

Aggregation Approach

Internal Validity: Parallel Trends

- If the parallel trends assumption is not satisfied, the resulting savings estimate may be biased.
- While the weighting based on study design implicitly addresses aspects of parallel trends, Guidehouse includes an additional weight for studies that aimed to address the potential for bias resulting from a violation of the parallel trends assumption.
- Key considerations:
 - Higher weights were assigned to studies using experimental design, and studies which excluded customers who experienced major lifestyle/home renovation concurrent with the analysis period (e.g., purchase of an electric vehicle, occupancy changes, renovations, etc.)

Parallel Trends	Weight	Number of Studies
Reasonable Adjustment or No Adjustment Necessary	0.90	8
Not Addressed or Adjustment Not Made	0.10	11
Total	1.0	19

Aggregation Approach

Internal Validity: Data Type

- Hourly consumption data (AMI) allows an evaluation to capture hourly variation in response to time-varying factors, such as weather
- Key considerations:
 - Given smart thermostat savings is highly dependent on weather, Guidehouse applied a weighting scheme which prioritizes the use of AMI data relative to monthly data

Data Type	Weight	Number of Studies
Hourly/Daily	0.60	8
Monthly	0.40	11
Total	1.00	19

Aggregation Approach

Internal Validity: Study Quality

- Studies with the highest study design quality should have the largest influence for savings values in the MEMD
- Key considerations
 - Guidehouse conducted a *qualitative* assessment of study quality, weighting studies based on a rating of high, medium, low. For example, we examined:
 - Quality of matches during the baseline period
 - Distribution of demographic variables between participant/comparison groups
 - Robustness checks

Study Quality	Weight	Number of Studies
High	0.80	11
Medium	0.20	8
Low	0.00	0
Total	1.00	19

Aggregation Approach

Internal Validity: The Inverse of Relative Precision*

- Relative precision** is the ratio of the precision of a given measurement and the value of the measurement itself
 - Interpretation of relative precision – the lower the value, the higher the certainty of the estimate
- Guidehouse calculated the inverse of the relative precision for each study to provide studies with more certainty surrounding the savings estimates with higher weights
 - Relative precision was calculated at the 90% confidence level for all studies
 - For studies that did not report standard errors or confidence intervals, Guidehouse assigned a weight of 0.025 so the results are still included in the analysis but with a high degree of uncertainty

Statistics	Weight	Number of Studies		
		Electric Cooling	Electric Heating	Gas Heating
200%+	0.475	5	0	6
100%-200%	0.375	4	2	2
<100%	0.125	0	1	1
Missing Standard Errors/Confidence Interval	0.025	5	2	4
Total	1.000	14	5	13

* The inverse of relative precision equals one divided by the relative precision
 ** Relative precision equals the 90% confidence interval divided by the energy savings point estimate

Aggregation Approach

External Validity

- Savings (both in absolute and in percentage terms) may vary with population-level attributes
- Guidehouse developed weights for population-level attributes expected to be correlated with smart thermostat savings using NOAA, RECS 2020 (released in June 2022)
 - Climate Zone
 - Housing Characteristics (Age of Housing Stock, Home with Basement, Home with Double/Triple Pane Windows)
 - Household Characteristics (Income, Age*)
 - Prevalence of Smart Thermostats

*Age of the householder that completed the RECS questionnaire.

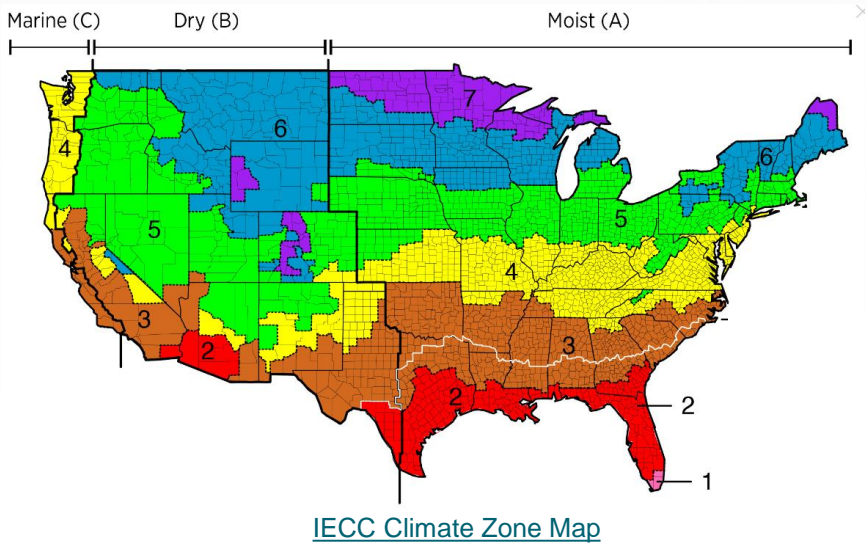
Aggregation Approach

External Validity – Climate Zone

Michigan within
climate zones 5
and 6

Climate Zone	Weight	Number of Studies
N/A *	0.00	1
1	0.00	0
2	0.025	5
3	0.025	2
4	0.075	4
5	0.40	4
6	0.40	1
7	0.075	2
Total	1.00	19

*One study spanned across the US, and so smart thermostats were not included in just one climate zone. This study also did not include a comparison group, and so it was effectively dropped due to study design.



Aggregation Approach

External Validity – Housing Characteristics

Michigan: 12%

House Built 2000 or Later	Weight	Number of Studies
10-20%	0.50	14
21-30%	0.35	5
31-40%	0.15	0
Total	1.00	19

Michigan: 71%

Single Family Proportion	Weight	Number of Studies
51%-60%	0.15	3
61%-70%	0.35	2
71%-100%	0.50	14
Total	1.00	19

Michigan: 62%

House with Basement	Weight	Number of Studies
20% or less	0.10	9
21-40%	0.15	2
41-60%	0.35	6
61%-80%	0.50	2
Total	1.00	19

Michigan: 68%

House with Double/Triple Pane Windows	Weight	Number of Studies
51%-60%	0.25	7
61%-70%	0.50	4
71%-80%	0.25	8
Total	1.00	19

Aggregation Approach

External Validity – Household Characteristics

Michigan: 48%

Household Income Greater than \$60,000	Weight	Number of Studies
<46%	0.25	0
46-50%	0.40	10
50-55%	0.25	7
55%+	0.10	2
Total	1.00	19

External Validity – Smart Thermostat Prevalence

Michigan: 15%

Households with a Smart Thermostat	Weight	Number of Studies
8%-12%	0.4	5
12%-16%	0.6	14
Total	1.00	19

Michigan: 16%

Age of Householder between 35-44 years	Weight	Number of Studies
13%-15%	0.3	8
15%-17%	0.4	5
17%+	0.3	6
Total	1.00	19

Analysis of Savings Values

To develop the proposed savings values, Guidehouse completed the following steps:

1. Guidehouse converted savings values for included studies into percent of electric cooling load, electric heating load, and gas heating load
 - In studies where the % savings are not reported with respect to the heating or cooling load, Guidehouse made assumptions to derive the percent savings using publicly available data sources, including the EIA’s [Residential Energy Consumption Survey Data](#), [NOAA](#), and [2019 CA RASS Study](#)
2. Assign the composite weight accounting for study analysis period, internal validity, and external validity to included studies
3. Calculate the weighted average of the savings estimates
4. Increase savings to reflect Thermostat Optimization (TO)
 - Most of the studies included were completed prior to TO being widely deployed thus savings represents savings for smart thermostats without TO. The few studies completed following widespread deployment presented savings for smart thermostats without TO.
 - TO was evaluated using RED or within-subject “Learning” and “Non-Learning Days” prior to widescale deployment. Guidehouse reviewed 8 studies to inform the TO savings adjustment.
 - Guidehouse assumes a 51% opt-in rate based on the study review and information provided by thermostat manufacturers

System Type	Electric Savings		Gas Savings	
	Study Result	Opt-In Rate Applied	Study Result	Opt-In Rate Applied
Electric Cooling	3.33%	1.69%	N/A	N/A
Electric Heating	3.2%	1.62%	N/A	N/A
Gas Heating	4.1%	2.08%	3.83%	1.94%

Thermostat Optimization Savings

Selected Studies

Study Title (Source Hyperlinked)	Author	State	Study Year
National Grid Massachusetts and Rhode Island: 2017 Seasonal Savings Evaluation	Navigant (Guidehouse)	Massachusetts/Rhode Island	2017
ComEd CY2018 Seasonal Savings Cooling Season Impact Evaluation Report	Navigant (Guidehouse)	Illinois	2018
2018 Massacuhsetts Summer Thermostat Optimization Evaluation	Navigant (Guidehouse)	Massachusetts	2018
Energy Trust of Oregon Resideo Thermostat Optimization Pilot Report	Apex Analytics	Oregon	2018/2019
2018-2019 Massachusetts Winter Thermostat Optimization Evaluation	Navigant (Guidehouse)	Massachusetts	2018/2019
Orchestrated Energy Impact Analysis - Summer 2019	Apex Analytics/Demand Side Analytics	N/A	2019
2019 Massachusetts Summer Thermostat Optimization Evaluation	Navigant (Guidehouse)	Massachusetts	2019
2019/20 Massachusetts Winter Thermostat Optimization Evaluation	Guidehouse	Massachusetts	2019/2020

Example Weighted Average Savings Calculation

Example Studies (A)	Weight #1 (B)	Weight #2 (C)	Weight #3 (D)	Total Weights (E) = (B) + (C) + (D)	Relative Weights (F) = (E)/Σ(E)	% Savings
Study #1	0.1	0.5	0.1	0.7	0.292	5%
Study #2	0.2	0.4	0.3	0.9	0.375	6%
Study #3	0.3	0.3	0.2	0.8	0.333	7%
Weighted Average						6.04%

Weighted Average = (0.292 x 5%) + (0.375 X 6%) + (0.333 x 7%)

All the values presented here are for illustrative purposes only.

Results

Electric Cooling Savings

Study	Relative Weights	% Savings
Evaluation of the 2013-2014 Programmable and Smart Thermostat Program, 2015 (NIPSCO)	0.12	16.10%
Evaluation of the 2013-2014 Programmable and Smart Thermostat Program, 2015 (Vectren)	0.12	13.90%
Analysis of Energy Savings for FPL's Customer Trials of the "Learning Thermostat TRM v4.0 Recommendations for Residential Thermostats and Heating and Cooling Equivalent Full Load Hours	0.11	7.70%
Impact Evaluation of Smart Thermostats-PY 2018	0.10	13.20%
PG&E Smart Thermostat Study: First Year Findings (Thermostat 1&2)	0.10	2.54%
Residential Thermostat EE Program Evaluation	0.09	14.80%
ComEd Advanced Thermostat Evaluation: Final Research Report	0.08	6.20%
Xcel Energy Colorado Smart Thermostat Pilot – Evaluation Report	0.08	3.24%
Michigan Tier 3 Thermostat Calibration Study	0.07	10.93%
When are Smart Thermostats a Smart Investment? (Published in the 2019 IEPEC proceedings)	0.07	-4.70%
Weighted Average Savings		7.62%
Adjusted Savings*		9.31%

*Adjusted Savings = Weighted Average Savings + (TO Savings*TO Opt-in rate)

Heating Savings, Gas & Electric System Types

Study	Heating System Type	Relative Weights	% Savings
Evaluation of the 2013-2014 Programmable and Smart Thermostat Program, 2015 (NIPSCO)	Gas	0.08	13.40%
Evaluation of the 2013-2014 Programmable and Smart Thermostat Program, 2015 (Vectren)		0.08	12.50%
Northwest Smart Thermostat Research Project		0.07	7.60%
TRM v4.0 Recommendations for Residential Thermostats and Heating and Cooling Equivalent Full Load Hours		0.07	5.10%
Impact Evaluation of Smart Thermostats - PY 2018		0.07	1.13%
PG&E Smart Thermostat Study: First Year Findings (Thermostat 1&2)		0.06	1.90%
Residential Thermostat EE Program Evaluation		0.06	1.90%
Residential Smart Thermostats, Illinois, 2015		0.05	6.70%
Energy Trust of Oregon Smart Thermostat Pilot Evaluation (Thermostat 1)		0.05	6.60%
Getting Smarter? Evidence of Savings from the Nest Thermostat		0.05	5.36%
Recurve Smart Thermostat Impact Analysis Reports 2015-2017		0.05	6.34%
Michigan Tier 3 Thermostat Calibration Study		0.05	4.20%
Xcel Energy Colorado Smart Thermostat Pilot - Evaluation Report		0.05	2.30%
Impact Evaluation of Smart Thermostats - PY 2018	Electric	0.07	2.07%
PG&E Smart Thermostat Study: First Year Findings (Thermostat 1&2)		0.06	1.30%
Michigan Tier 3 Thermostat Calibration Study		0.05	4.70%
When are Smart Thermostats a Smart Investment? (published in the 2019 IEPEC proceedings)		0.04	-3.90%
Weighted Average Savings			5.05%
Adjusted Savings*			6.91%

* Adjusted Savings = Weighted Average Savings + (TO Savings*TO Opt-in rate)

Electric Heating Savings, Gas System Type

Study	Relative Weights	% Savings
N/A – Insufficient evidence regarding impacts to electric consumption		
Adjusted Savings*		2.08%

* Adjusted Savings = Weighted Average Savings + (TO Savings*TO Opt-in rate)

Your Guides

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